

# **Fabrication and Qualification of Small Scale Irradiation Experiments in Support of the Accident Tolerant Fuels Program**

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February 2016



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**February 2016**

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Idaho Falls, Idaho 83415**

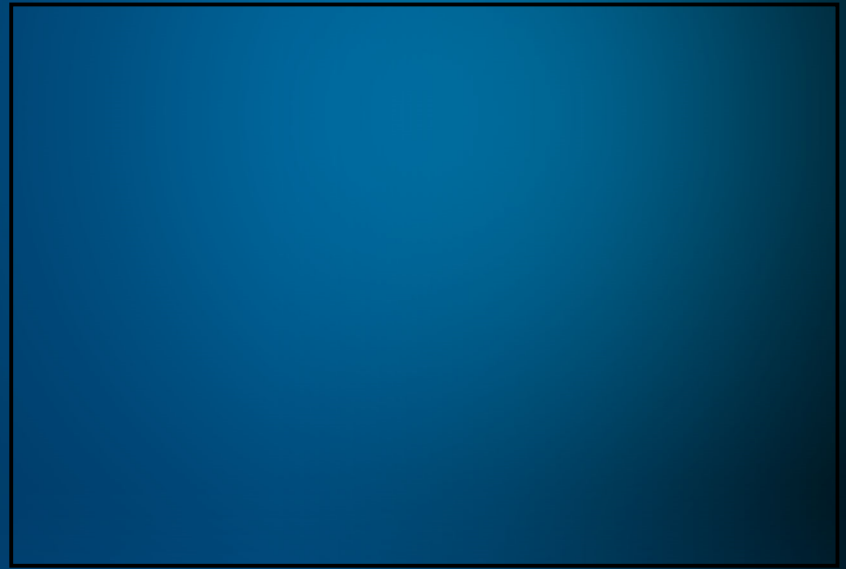
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# Acknowledgements

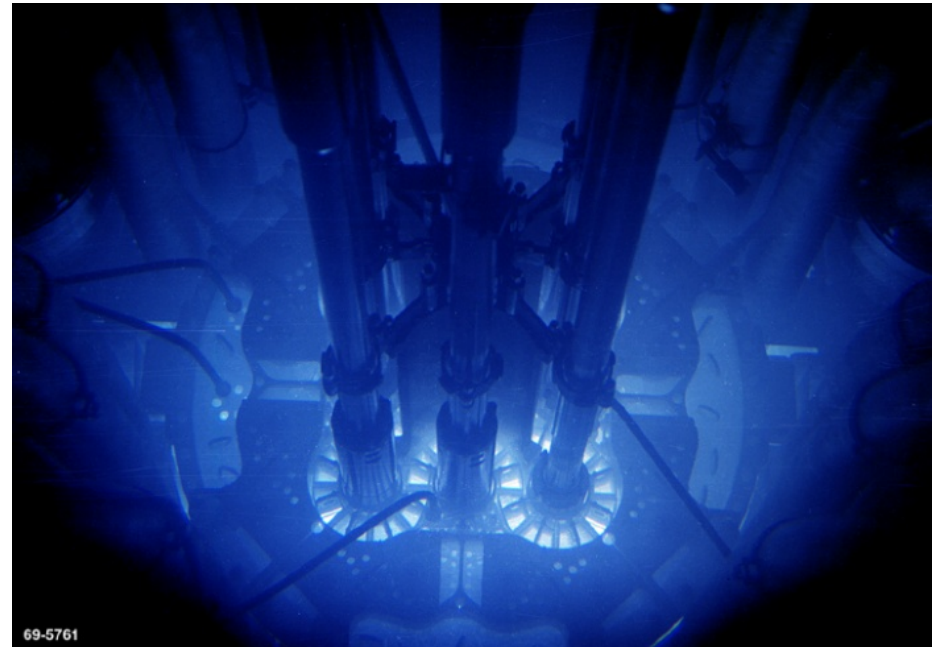
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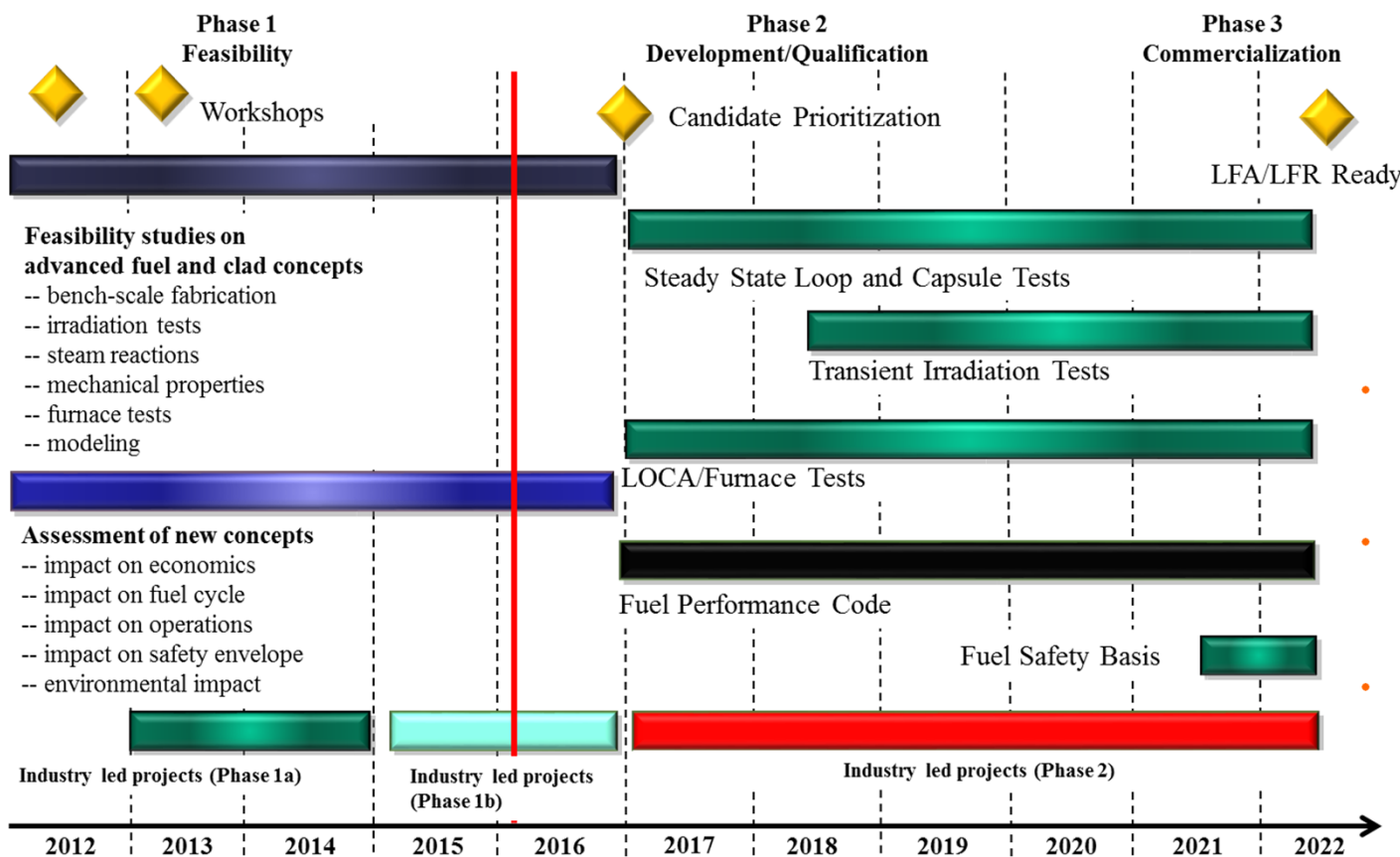
# ***ATF Overview***

- ATF Overview
- Fabrication
  - Components
  - Experiment Assembly
- Qualification/Validation
- Challenges
- Current and Future Activities



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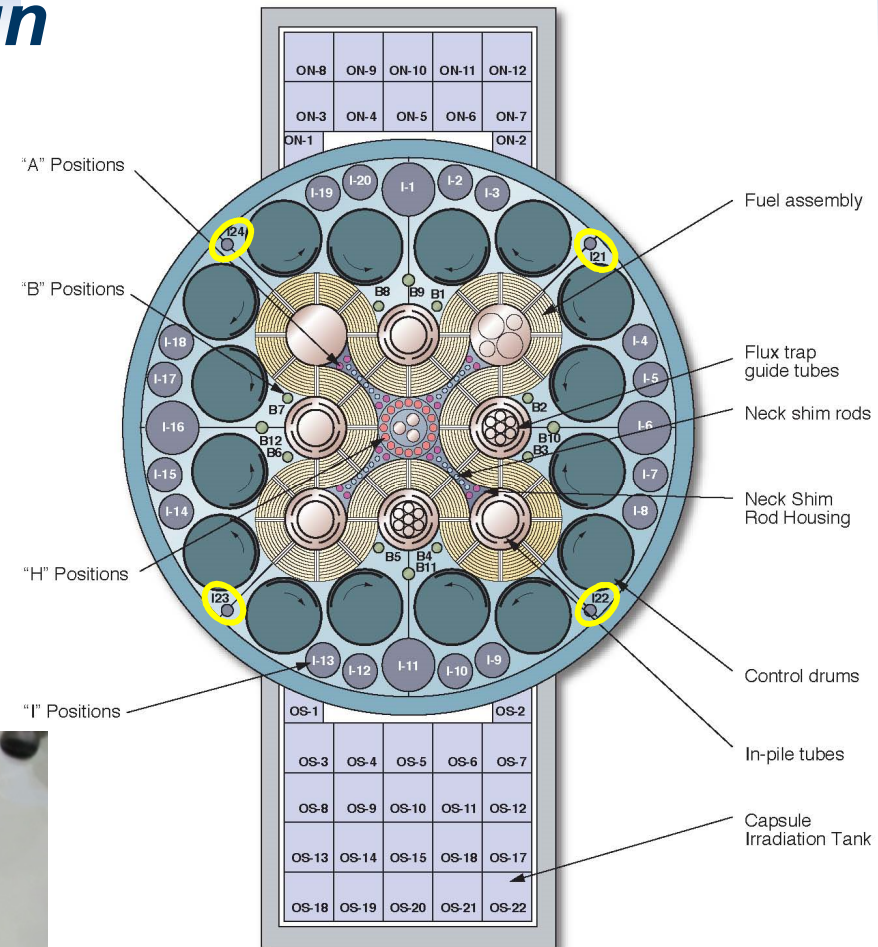
# ATF Introduction



- Accident Tolerant Fuels Goals
  - Develop LWR fuels to improve the following during normal and accident conditions:
    - *Performance*
    - *Reliability*
    - *Safety*
  - Innovative materials being tested must perform better than  $\text{UO}_2\text{-Zr}$  system
- ATR research will support
  - Commercial reactor demonstration of LFA or LFR by 2022
- ATR drop-in capsule experiments being tested as part of Phase 1 “proof of concept”
- ATR loop test to be conducted as part of Phase 2
  - Currently in planning stages

# ATF-1 Experimental Design

- Small I positions in the ATR
  - Experiment basket has 3 channels
  - Each channel contains vertical stack of rodlets in capsules (up to 7 x 6-in. capsules)
  - Experiment safety limits
    - LHGR  $\leq 650$  W/cm
    - Capsule pressure  $\leq 800$  psi

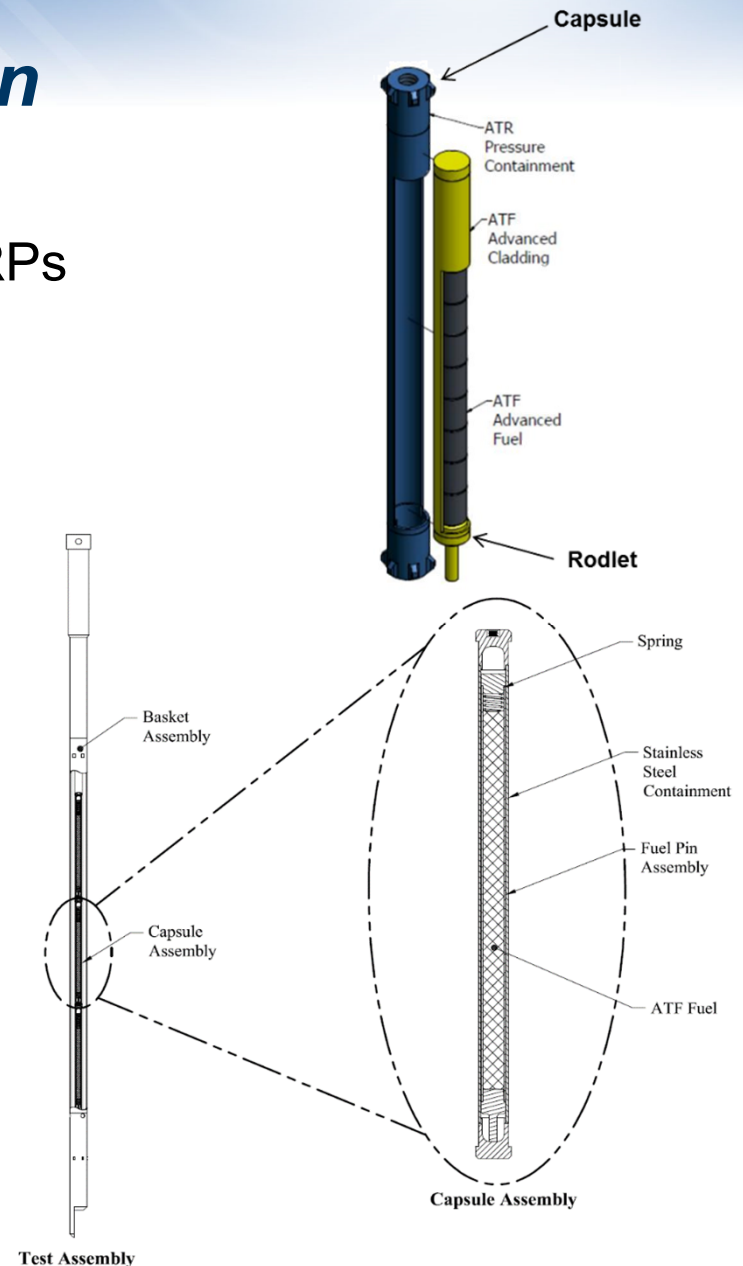


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# ATF-1 Drop-In Capsule Design

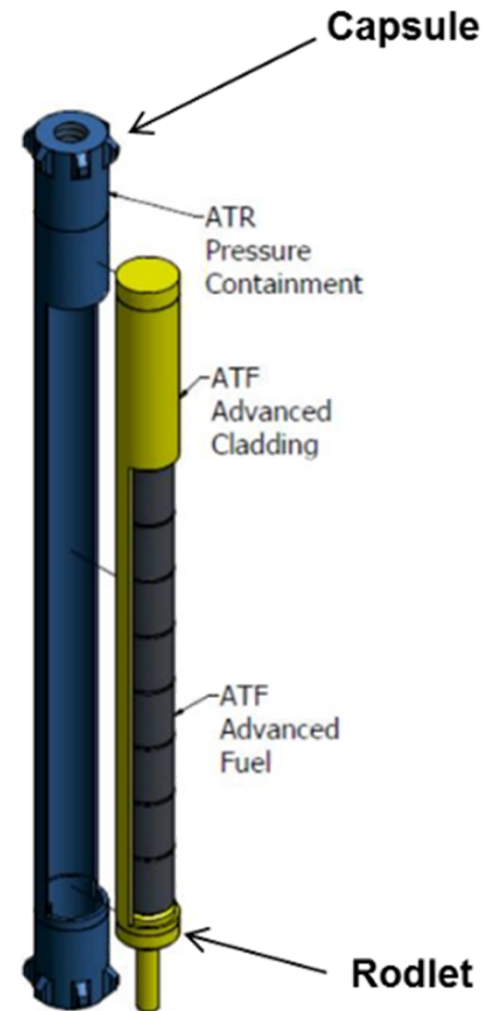
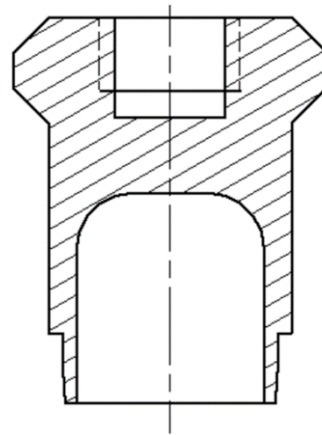
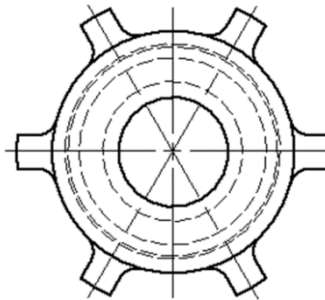
- Experimental fuels and cladding concepts
  - Teams from industry, national labs, IRPs

Fuel Type	Cladding Type
$U_3Si_2$	Zirlo
$UO_2$	Zircaloy-4
$UO_2$ + SiC whiskers	Zircaloy-4
$UO_2$ + diamond particles	Zircaloy-4
$UO_2$	APMT
$UO_2$	Alloy 33
$UO_2$	FeCrAl



# ***Rodlet and Capsule Component Fabrication***

- Wire EDM
- Gun Drill
- Hone
- CNC Lathe
- Laser Etch
- Inspections





# Component Fabrication



Honing machine used to hone inner diameter of tubing. Can hold tolerances of  $\sim 0.0003$ " or less



Laser engraving system to mark rodlet and capsule components



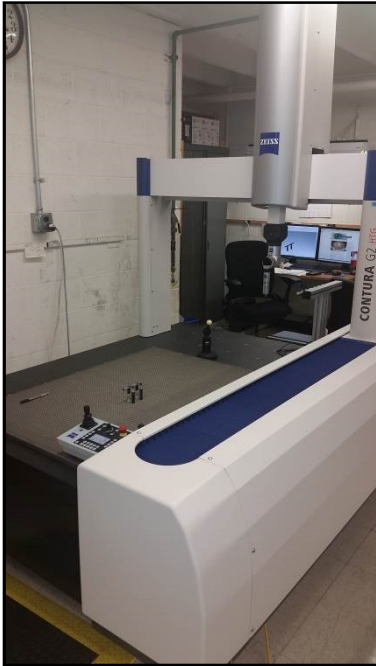
Haas SL30 CNC lathe used to machine rodlet/capsule components



Laser etching on rodlet endcaps

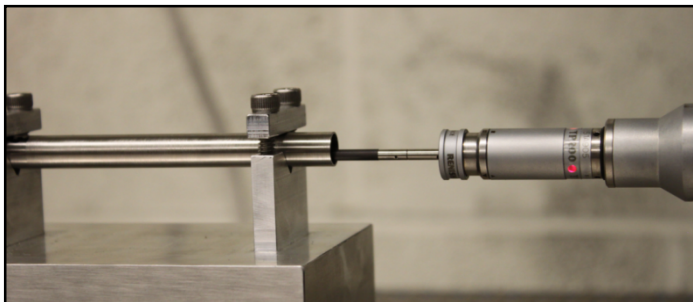


# Inspections



New Zeiss CMM-  
higher accuracy  
of measurement.

Capability to scan  
over surfaces (as  
opposed to  
measuring  
individual points)

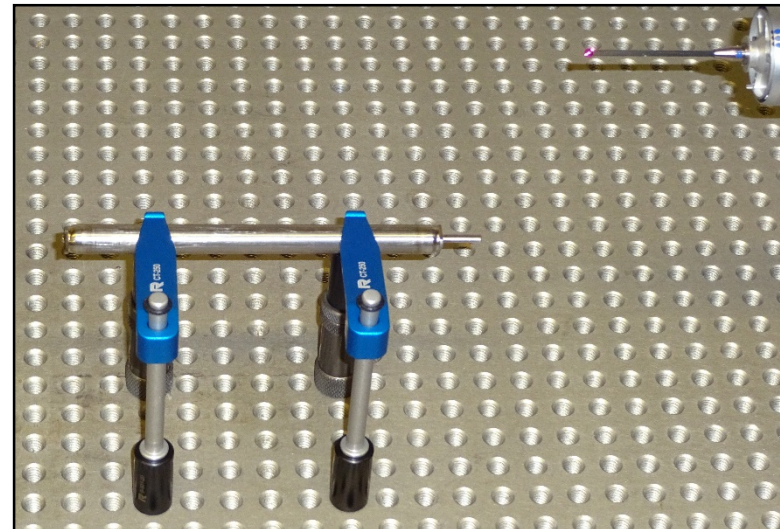


Wall thickness determined via ID and OD  
measurement points



**Left:** Fully inspected  
capsule endcaps with  
quality status indicator  
("green tag")

**Below:** Fueled rodlet  
assembly on CMM



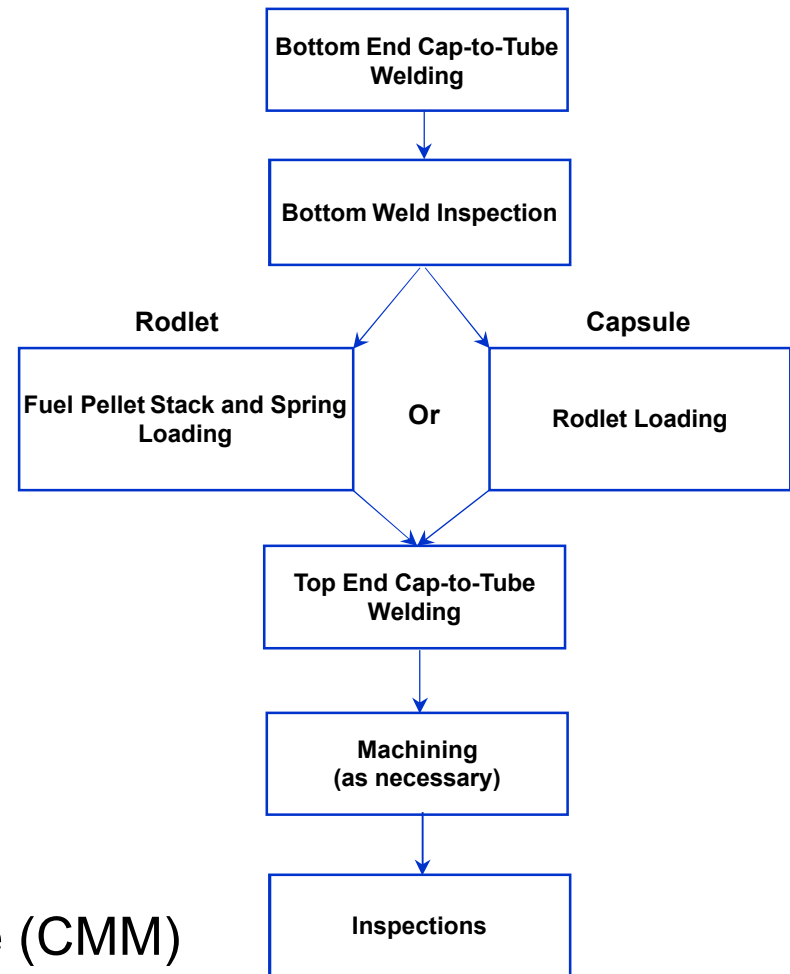
# Assembly/Inspection

- **Experiment Assembly**

- Loading
- Welding
- Machining

- **Inspections**

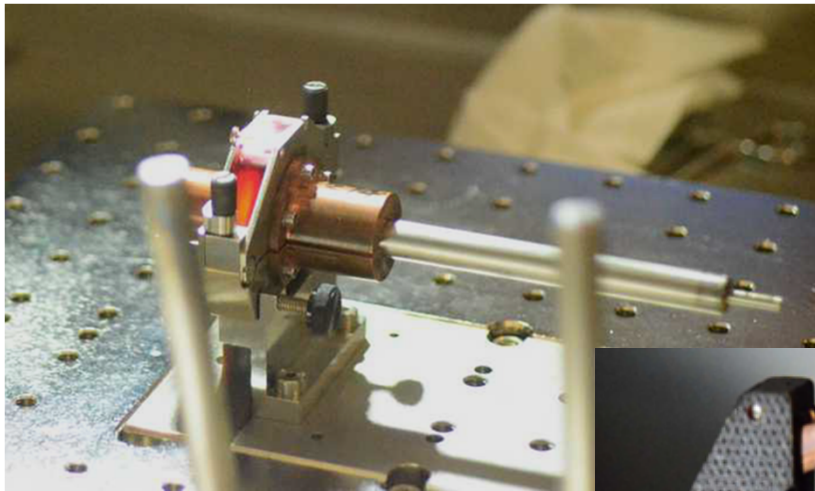
- Helium Leak Check
- Dye Penetrant testing
- Radiography
  - Computed Radiography
  - Digital Radiography
- Dimensional Inspection
  - Coordinate Measuring Machine (CMM)





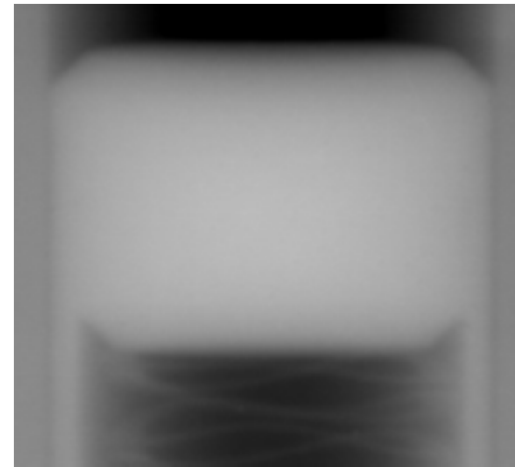
# Assembly

- Arc Machines Inc. (AMI) orbital tube welding system
  - Final assembly of rodlet and capsule assemblies
- Mbraun glovebox for inert atmosphere
- Assembled rodlets machined on Haas TL-1 lathe to fit into capsules



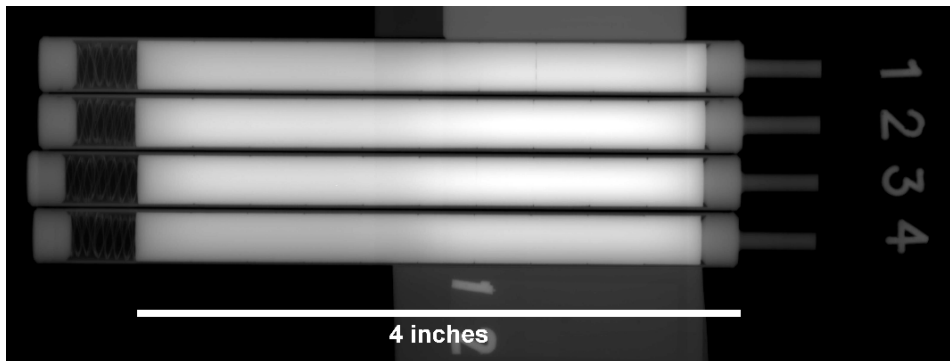
# Qualification

- Radiography
  - Computed radiography (CR)
    - Welds
    - Fuel/rodlet location
  - Micro-focus digital radiography (DR)
    - ~5x the resolution of CR system
  - Evaluating CT system

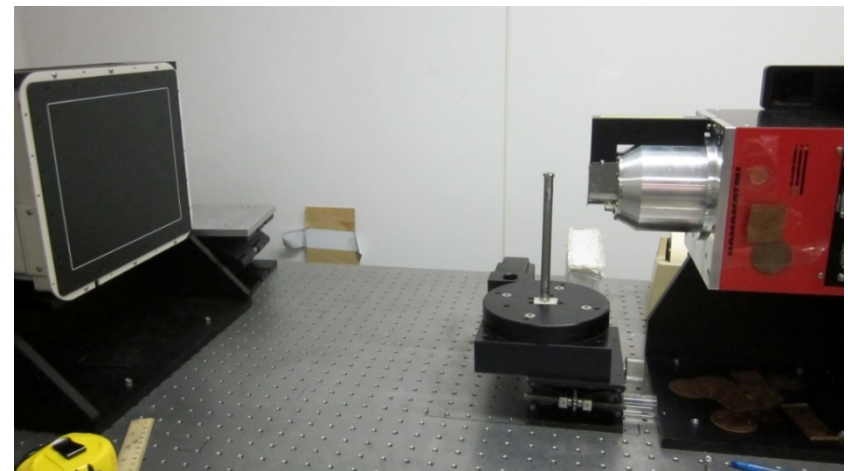


**Left:** Digital radiography of rodlet endcap

**Below:** Setup of digital radiography system

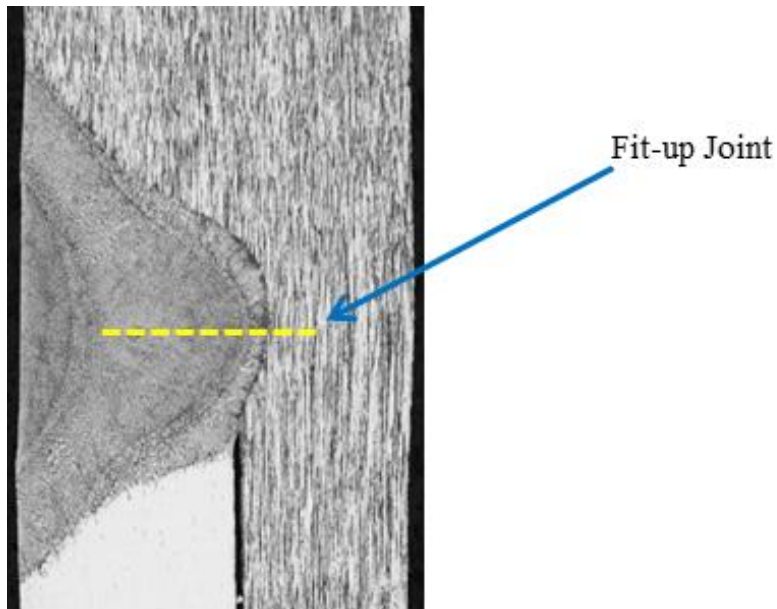
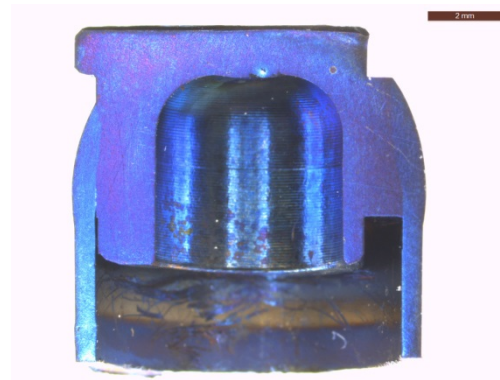


Fuel location radiograph of ATF rodlets (computed radiography)



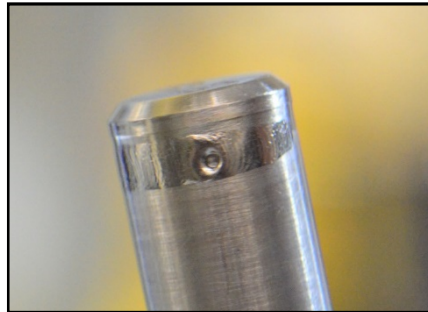
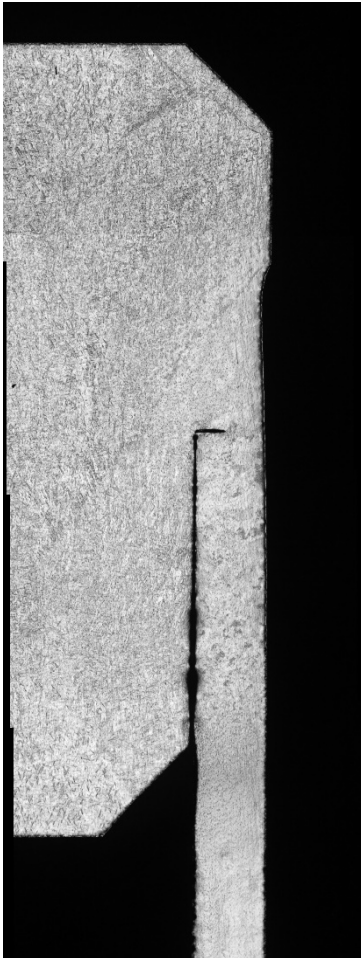
# Qualification

- **Metallography**
  - Etching
  - Heat tinting
- **Hydrostatic rupture tester** installed for burst testing
  - Validation of design and assembly parameters





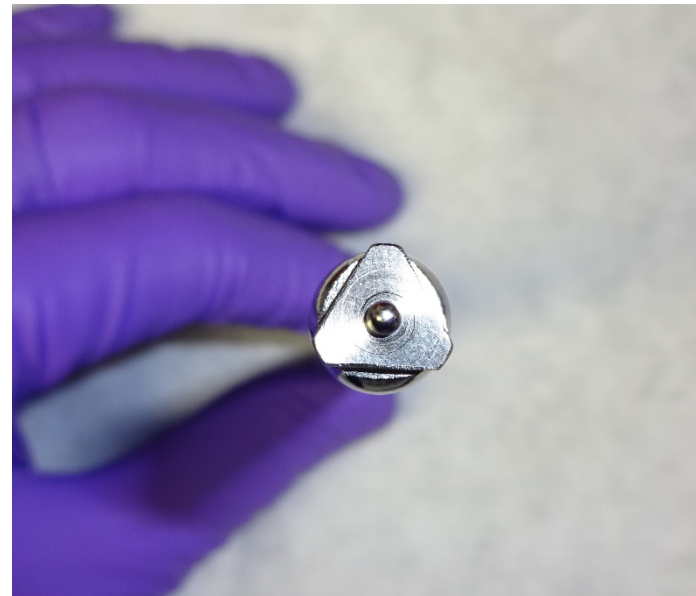
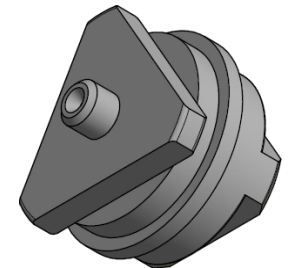
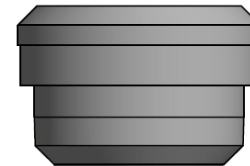
## Initial Issues



- Welding difficulties due to design and poor component fit-up necessitated process improvements:
  - Tighter component tolerances
  - Taper on rodlet endcap
  - Adjusted cleaning requirements of components
  - Alignment tools for tungsten positioning
  - Additional copper chill blocks
- *Successfully qualified 19 capsule assemblies for ATR insertion in initial ATF-1 campaigns*

## Design Change

- Rodlet endcap design modified from solid plug to hollow design
- Addition of weep hole to mitigate gas expansion
  - Required establishment of micro-TIG torch in glovebox for closure
- Different centering mechanism



## ***Current***

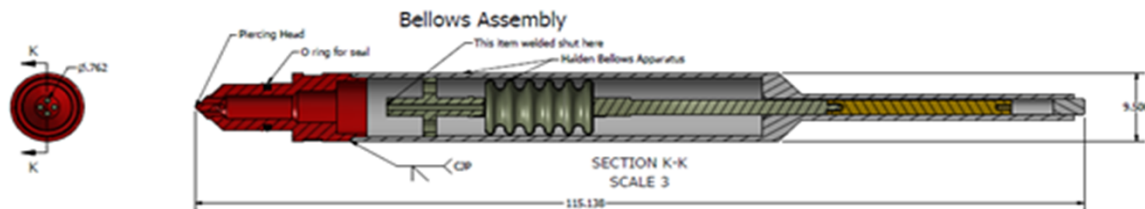
- New issue with latest capsule welds
  - May be attributed to sulfur content in new heat of SS316L capsule material
  - Resolution is in-process and ongoing
- First experiments from ATF-1 campaign to be shipped for PIE later this month
- Additional fabrication campaigns within ATF-1
  - AREVA
  - Oak Ridge National Laboratory
  - Los Alamos National Laboratory
- Evaluating additional assembly techniques
  - Laser welding
  - Pressure resistance welding

## *Future*

- ATF-2 is currently in the design and development stages
  - Prototypical PWR conditions
  - Loop test with instrumented fuel pins
    - Live instrumentation in some of the pins for real time data collection
      - LVDT's
      - Temperature sensors
      - Neutron detector
    - Additional instrumentation for data collection between reactor cycles
  - Many supporting efforts
    - ATRC runs
    - Autoclave test
    - Sensor qualification test

## ATF-2 Design

- Modular test train assembly containing 5 tiers
  - Each tier contains 6, 6" or 12" fuel pins
  - Instrumented pins in top tier
  - Remaining pins may contain LVDT's for measurements between cycles
    - Also designed to allow for additional instrumentation after ATR irradiation, prior to transient testing



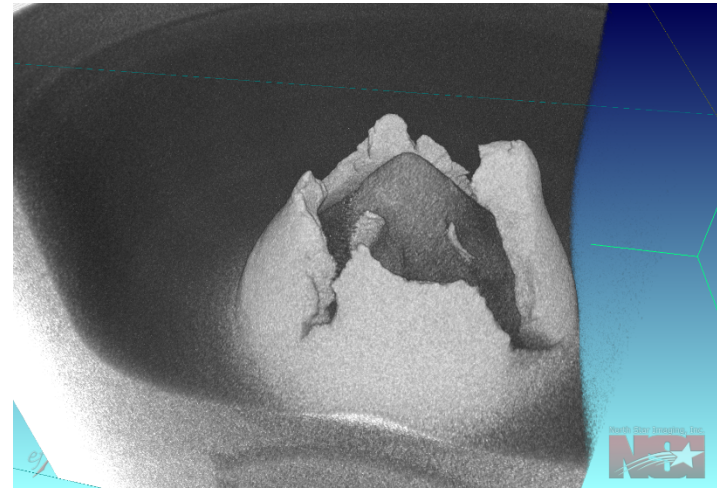
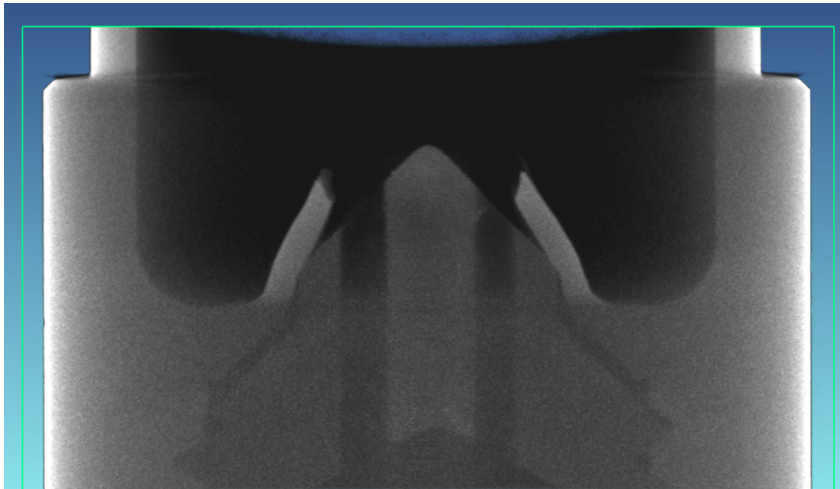
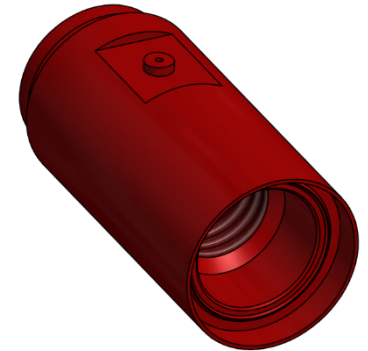
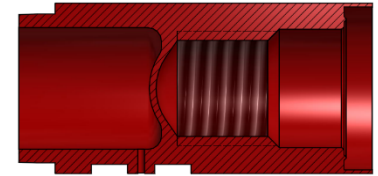
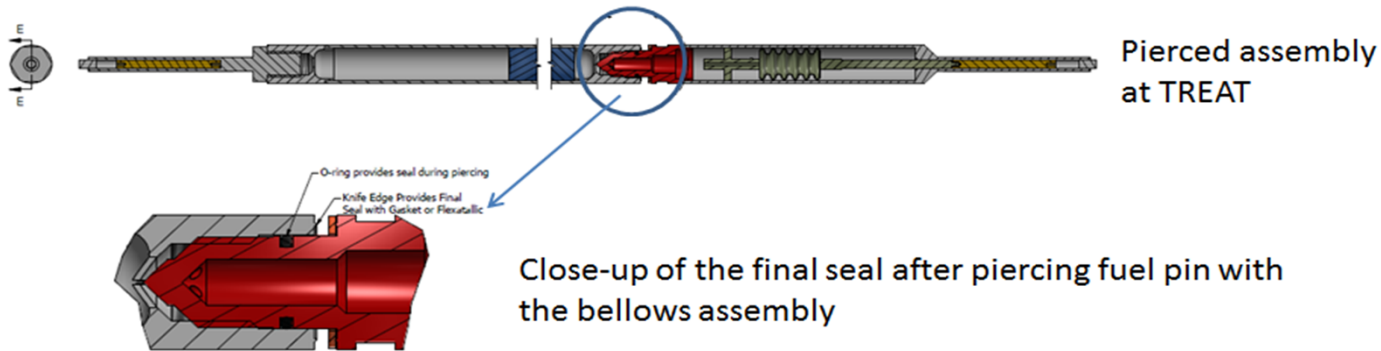
Bellows Assembly used to pierce irradiated fuel pins at TREAT

ATR fuel pin assembly





# ATF-2 Design



## *Summary*

- Multiple successful fabrication campaigns
  - First set of ATF-1 experiments scheduled for PIE this year
- New rodlet endcap design for improved fabrication success
- Established new capabilities to support fabrication
  - Rupture testing
  - Micro-TIG torch
- ATF-2 in the design and development stages
  - Scheduled for ATR insertion in mid-2017



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